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COMPLETE SPECIFICATION

Propellers, and Convertiplanes Equipped Therewith

I, ARTHUR MIDDLETON YOUNG, a Citizen of the United States of America, of Paoli, County of Chester, State of Pennsylvania, United States of America do hereby declare the invention, for which I pray that a patent may be granted to me, and the method by which it is to be performed to be particularly described in and by the following statement:—

This invention relates to a propeller.

This propeller may be used on a convertiplane type of aircraft that is, one which is capable of taking off, flying and landing as a helicopter and also is capable of being readily converted into an airplane (aeroplane) for forward flight at high speed and the invention also extends to such a convertiplane.

Convertiplanes present the problem of providing thrust means that have the capability both of lifting the aircraft in its helicopter phase, and propelling it forward at high velocity in the airplane phase. To provide a propeller that is suitable both for the helicopter phase and for the airplane phase leads to what may be called the predicament of convertiplane design.

This predicament stems from a law of physics that states that power is the product of force times velocity, so that for a given engine power one may have either a large force at low velocity (such as the lift of a helicopter rotor) or a small force at high velocity (such as the thrust of an airplane propeller, or to take a more extreme case the thrust of a jet engine).

Aircraft depend for their motion on the reaction produced by imparting a change of momentum to a column or jet of air, by giving to the air a rearward or downward velocity, and employ for this either rotors (as in helicopters) or propellers or jet engines (as in airplanes). The mass and hence the diameter of this column or jet of air can be great for the slow speed vehicle but, for a given engine power, must grow progressively less as the velocity which the aircraft is capable of attaining is greater. Thus, the large helicopter rotor and the large diameter column of air it moves is associated with a velocity of vertical climb of some 20 miles per hour, the 10 foot airplane propeller with a velocity of some 200 miles per hour, the 3 foot jet with a velocity of some 600 miles per hour. In other words, as the diameter of the column or jet stream is reduced, the velocity at which thrust is available increases but the thrust it produces (for a given power) is reduced.

This principle then requires that the diameter of the thrust means, or the diameter of the column or jet of air acted on, be reduced as the velocity expected of the aircraft increases. Fortunately for the designer this principle allows lee-way and permits a given device such as a propeller to have a considerable range of velocity over which it is efficient. Thus an airplane propeller which is designed for maximum efficiency at the cruising speed of the airplane, is still reasonably efficient at lower and at higher speeds so that over a range of speed of from say 100 miles per hour (take off speed) to 300 miles per hour (top speed, the airplane propeller is within a few percent of maximum efficiency. This result stems from the nature of the curve of efficiency against velocity, this curve rising to a maximum and then falling off, but having near the maximum a region where it is substantially flat, that, is, in which the efficiency does not drop off more than a few percent. Beyond this region the efficiency however falls at a progressively greater rate.

This range of speed in which reasonable efficiency is possible underlies not only propellers but all aerodynamic devices, and

makes it possible for the airplane wing to have a speed range of about 3 to 1. It even, in an indirect manner, makes possible the translational motion of the helicopter by permitting differential air velocity over the advancing and retreating helicopter blades.

Therefore, the fundamental curve that would show diameter of the thrust means versus speed must be modified and must be visualised not as a sharp line, but as a broad band whose centre moves down (indicating a smaller diameter) as the velocity increases.

Convertiplanes have been successful in proving the fundamental principle that an aircraft may be designed which takes off as a helicopter and converts to flight as an airplane, but hitherto such aircraft have been disappointing in performance or speed. Either they have used a small diameter propeller in both the helicopter and airplane phases, thus retaining the high speed quality of an airplane in both phases at the expense of very limited load capacity, (only 3 lbs, per horsepower), or they have used large diameter rotors in both phases and had a maximum speed only slightly in evcess of a pure helicopter. In either case they have not justified the claims made for the convertiplane, i.e. that it would combine the vertical life of a helicopter with the speed of an airplane.

In order to improve such performance it is necessary to attain good efficiency at both ends of the speed range. This means that, if the same propeller is to be used for thrust and for propulsion, the speed range of the propeller must be extended well beyond the 3:1 value available normally. It has in fact to be extended by as much as the speed is to be increased over that of a pure helicopter of the same lifting capacity and power. This is not possible with propellers hitherto in use.

The present invention deals with the problem of obtaining efficiency at both ends of the speed range by providing means for varying the propeller diameter so that for take-off and landings the propeller is expanded and in high speed flight it is contracted.

According to the invention a variable diameter propeller assembly comprises at least one blade having an inboard section and an outboard section retractable with respect to the inboard section, means for retracting the outboard section, and driving means for rotating the blade and for imparting torque to the retracting means, so arranged that when the torque imparted to the retracting means exerts a force on the outboard section that exceeds the centrifugal force thereon the outboard section is retracted.

A superficial consideration might seem to require a change in diameter from say 40 feet as a helicopter rotor to one of say 10 feet as an airplane propeller, but such a change (which would be very difficult from a mechanical standpoint) is not necessary or even desirable as can be shown from theoretical considerations, confirmed by extensive tests I have made to establish this design criterion.

There now follows an explanation as to why the present invention improves the high speed efficiency without having to make the large change of diameter (from 40 feet to 10 feet, for example).

It should first be noted that an airplane, for reasons such as ground clearance and engine speed, favours as small a propeller as efficiency will permit, and that, generally speaking, a helicopter, whose lift is supplied at all times by the rotor, uses as large a rotor as is conveniently possible, because other factors being equal, the power required is inversely proportional to the rotor diameter.

Therefore, it will be realized that for a convertiplane, which operates only for a short time as a direct lift device, the ideal rotor diameter for the helicopter phase may be smaller than the pure helicopter, and also that in the airplane phase the ideal propeller may be considerably larger than is customary in a pure airplane. This brings the two requirements closer and reduces the percentage change of diameter required. To discover what this change of diameter should be more accurately, it is necessary to make some brief computations.

The basic formula for rotors of similar proportions is:

Power required $=C_p\ n^3\ d^5$ where C_p is power coefficient

n is angular velocity in radians/sec.

d is diameter

The formula for torque is similar but n here occurs to the second power:

Torque $=C_p\ n^2\ d^5$

The problem in switching from a low velocity to a high velocity is the variation in C_p—the power coefficient. This changes rapidly with the pitch setting of the propeller, and its values may be determined from NACA (National Advisory Committee for Aeronautics, United States of America) and other tests of propellers. A typical value of C_p for angles of attack suitable for helicopter lift is about 0.1, and a value of C_p for the airplane phase (angle of attack say 45°) is 0.5, i.e., a five-fold spread. This implies that for the condition of constant rotor or propeller speed the power coefficient for the airplane condition will be five times the power coefficient for the helicopter condition. This difference in power coefficient is to be compensated by a change in diameter, so that actual torque on the engine shaft is constant.

However, the formula above involving diameter to the fifth power cannot be used because that formula is for similar blade

shapes, and it is here proposed that the blade diameter be reduced but not the blade chord. This leads to a modified formula:

Power $= C_p\, n^3\, d^4$

Torque $= C_p\, n^2\, d^4$

Hence, for propellers of constant blade chord, where D and d are the diameters for helicopter condition and airplane condition respectively:

$$\left(\frac{D}{d}\right)^4 = 5$$

$$\frac{D}{d} = 1.50$$

that is, the diameter reduction to cover a power coefficient range of 5 is 33.3%.

This is actually less than the range afforded by the embodiments which will be described in the present specification, which afford about a 40% decrease in diameter $\left(\frac{D}{d} = \frac{10}{6} = 1.66\right)$ The calculation, however, does not take into account that the inboard section must be of slightly greater chord and thickness to accommodate the outboard section in a telescoping manner, hence, that a somewhat more than 33.3% diameter change is necessary.

Now referring to Figure 1 of the accompanying drawings, it will be seen how this change in propeller diameter is effective in increasing the high speed of the convertiplane provided with a variable diameter rotor. Figure 1 is a graph charting efficiency of different diameter propellers at different speeds. The curve aa^1 represents the propeller diameter for maximum efficiency, the upper curve bb^1 represents the maximum propeller diameter for which efficiency is above an acceptable minimum and lower curve cc^1 represents the minimum propeller diameter for which efficiency is above an acceptable minimum. The horizontal line d, d^1, d^{11} represents a given propeller diameter. The point d^1 is its intersection with the curve cc^1 and the point d^{11} its intersection with the curve bb^1. The segment $d^1\, d^{11}$ of this line represents the operating range for a suitably designed aircraft using this diameter propeller, the points d^1 and d^{11} representing its minimum and maximum speeds respectively, which might be, say, 100 and 250 mph. Now consider the line ff^1, which is illustrative of the diameter of a rotor of a helicopter or of a convertiplane, its capability of vertical take-off being indicated by the point f being on the y axis at zero velocity. Such a rotor thus has a maximum speed indicated by the x coordinate of the point f^1 of, say, 100 miles per hour. To go faster is impossible because in the region outside that bounded by the curves aa^1 and bb^1 the efficiency is not adequate for level flight. A reduction of the diameter from the value f to the value d will however permit the aircraft to attain the greater speed represented by the point d^{11}, the maximum speed of an aircraft with a propeller of diameter d.

The diagram shows not only the range of speed available without change in diameter (the range f—f^1) but the additional speed available when a diameter change is made possible, the stepped line $f\, f^1\, d^1\, d^{11}$. Conversion may be made gradually as speed is gained, the aircraft having surplus performance as long as it is within the boundaries defined by the curves bb^1 and cc^1.

This invention provides a variable diameter propeller equipped with means for extending and retracting the blades while the propeller is in operation taking into consideration the very large stresses and forces that act on these blades.

The invention may be performed in various ways, and some specific embodiments will now be described by way of example with reference to Figures 2 to 10 of the accompanying drawings, in which:—

Figure 2 is a fragmentary perspective view of a nacelle with one form of propeller assembly embodying the invention mounted thereon;

Figure 3 is a side view, in partial section, of a part of the propeller assembly of Figure 2 showing the propeller blade retracting means;

Figure 4 is a part-sectional plan view of the part of the propeller assembly shown in Figure 3;

Figure 5 is a side view, in section, of a second form of retracting means;

Figure 6 is a side view, in section, of a third form of retracting means;

Figure 7 is a perspective view of one form of convertiplane utilizing propeller assemblies of this invention, in its vertical take-off condition;

Figure 8 is a fragmentary perspective view of the convertiplane of Figure 7 shown in its forward horizontal flight condition;

Figure 9 is a perspective view of another form of convertiplane utilizing propeller assemblies of this invention; and

Figure 10 is a perspective view of yet another form of convertiplane utilizing a propeller assembly of this invention.

Nacelles and Propeller Assemblies

Referring to Figure 2 of the drawings, the reference character 15 denotes generally a nacelle adapted to house an engine 16 and mount a propeller assembly thereon. The engine 16 has an upwardly (for helicopter flight) or forwardly (for airplane flight) pro-

jecting drive shaft 17. Disposed at the outer end of this drive shaft is the propeller hub 18 having blades 19 mounted thereon.

Blade Length Varying Mechanism

Referring now to Figures 3 and 4, elevation and plan views of a first embodiment of the retracting mechanism of this invention are illustrated. The hollow inboard section 20 of a single blade 19 is shown. Two cables 21, 22 are secured to the inboard end 23 of the outboard section 24 of the blade. In this embodiment, the cables 21, 22 provide the means for transmitting force for retracting the outboard section 24, telescoping it within the inboard section 20, so that the blade 19 when fully retracted is about 50—60% of the overall length of the extended blade. This same mechanism may be used to retract the blades to a lesser degree if desired. The cables 21, 22 are secured to and wound around a winding drum 25 which is mounted on a drum shaft 26. This drum shaft 26 is rotatably mounted within the hub 18 between two drum mounting plates 27, 28 by means of bearings 29.

The drive shaft 17 extends through the hub 18 and is not directly attached thereto. Splined to the drive shaft 17 is a sungear 30 which transmits torque from the drive shaft to the drum 25 and the hub 18 at all times in the following manner. Torque is transmitted to the hub 18 through a plurality of planet gears 31 which mesh with the sun gear 30 and with a ring gear 32 which is mounted on and extends around the inner periphery of the hub 18. Torque is transmitted to the drum 25 through a spider 33 which is rotatably mounted on the drive shaft 17 beside the sun gear 30 and the planet gears 31. The planet gears are rotatably mounted on spindles 34 secured to the spider 33. Concentrically mounted on the spider is a drum drive gear 35 which meshes with a drum gear 36 which is splined to the drum shaft 26. Thus, any torque transmitted to the spider 33 is transmitted to the drum 25.

The division of engine power between the drum 25 and the hub 18 is accomplished by the elements just described in the following manner. When the drum 25 is stopped, the spider 33 is held in a set position with respect to the hub and although the planet gears 31 attached thereto serve to transmit torque to both the spider and the hub, because of the immobility of the spider, they serve to transmit all the power from the sun gear 30 to the hub. When the conditions are right for drum rotation, such as when the blade is extended and the centrifugal force on the outboard section is less than the force exerted on the outboard blade section by the torque transmitted to the drum, then part of the power from the sun gear 30 will serve to rotate the spider 33 with respect to the hub until the drum 25 is again stopped.

The propeller assembly thus provides two paths for transmission of power; one for driving the hub 18; the other for retracting the outboard sections 24. Torque is transmitted along both paths at all times and power is divided between them depending on pilot-controlled operating conditions to be described more completely hereinafter. If these conditions apply torque to the drum 25 which is opposed to and greater than the torque being transmitted via the drum path from the drive shaft, then all the drive shaft power will be transmitted to the hub. On the other hand, assuming conditions markedly decrease this opposing torque on the drum, then the spider and drum will be rotated with respect to the hub and a portion of the drive shaft power will be transmitted along both paths to rotate both the drum and the hub.

Referring to Figure 5, a second form of propeller assembly embodying the invention is illustrated. In this embodiment, a long, coarse pitch screw 37 is used to retract the outboard blade section 24. The screw 37 is engaged within an internally threaded nut 38 secured to the inboard end of the outboard section 24. The screw 37 extends along the centre of the hollow rotor blade 19, through articulating means 39 to a bevel gear 40 to which the screw is splined. The bevel gear 40 engages a larger bevel gear 41 which is splined on the extreme end of the drive shaft 17. The hub 18 is provided with bearings 42 at the lower part thereof where the shaft 17 enters the hub 18. As in the first embodiment, the hub 18 is driven only indirectly by the drive shaft 17. A stop mechanism (not shown) provides means whereby the otherwise operable retracting means comprising the screw 37 and nut 38 and the gears 40, 41 may be rendered inoperable and thus allow all the power of shaft 17 to be transmitted to the hub 18. The two paths for the transmission of the torque and power are as follows:

From the shaft 17 to the bevel gear 41 to the bevel gear 40 to the screw 37 and the nut 38. This retracts the outboard blade section 24. When the centrifugal force acting on the outboard section 24 of the blade 19 is greater than the retracting force produced by the torque transmitted to the gearing described above, the screw 37 cannot retract the section 24 and hence all the power is delivered to rotate the blades 19 through the bevel gear 41 and through the relatively stationary bevel gear 40. The force is applied, in this condition, through the inner end of the screw 37 and its bearings directly to the blades 19, causing rotation thereof. This state of affairs also exists when the stop mechanism is actuated. As in the first embodiment, power is always delivered to ensure

rotation of the blades 19; a part of the power may be branched off to retract the outboard sections 24 only when the balance of forces acting on the outboard sections permit.

Referring to Figure 6, another form of retracting mechanism is shown. In this embodiment, a cable 43 is secured by one end 44 to the inboard end of the outboard section 24. A pulley 45 is mounted for rotation in a vertical plane within the hub 18. The cable 43 is passed over the pulley 45, as shown, and is secured to an internally threaded nut 46 which is splined so that it can move longitudinally but not rotate within a hollow mast 47. The mast 47 is secured to the hub 18 but is mounted in bearings 48 at the output portion of the engine 16. The mast 47 is not driven directly by the engine 16.

A long, coarse pitch screw 49 extending from the engine 16 through the mast 47 and into the hub 18 functions as a drive shaft. The screw 49 is engaged within the nut 46, and hence can deliver power thereto when the balance of forces permit, causing the nut 46 to advance towards the engine 16 along the screw 49. This causes retraction of the cable 43 and the outboard section 24.

This embodiment operates according to the same basic principle as the embodiments already described. When the centrifugal force acting on the blade exceeds the torque imparted to the retracting mechanism, the outboard section 24 will not be retracted. All the power is then transmitted from the screw 49 to the nut 46 and thence to the mast 47 and the hub 18 to which the blades 19 are connected by the articulating means 39. As in the earlier embodiments, power is provided at all times to hub 18, but a portion of this power may be branched off in order to cause retraction, whenever the retracting torque exerts a force that exceeds the centrifugal force acting on the outer blade section 24.

Collective Pitch Control

Referring again to Figure 2, the propeller assembly of each of the embodiments of this invention may be provided with a collective pitch control mechanism 50 to effect collective pitch control of the blades 19. This collective pitch control mechanism comprises a conventional control stick and linkage (not shown) connecting the stick to a shaft 51. The shaft 51 is adapted to be moved longitudinally with control stick movements and is pivotally connected to one end of a bell crank lever 52 which is pivotally attached at 53 to the nacelle 15. The other end of the bell crank lever is pivotally attached to a sleeve 54 which is mounted concentrically on the drive shaft 17 and is attached to the inner non-rotating portion of a swashplate 55. Thus, longitudinal movements of the shaft 51 in response to collective pitch control stick movements will cause the swashplate 55 to move axially along the drive shaft 17 and, through links 56 and blade horns 57, to cause collective changes in the incidence settings of all the blades 19.

Cyclic Pitch Controls

Again referring to Figure 2, the propeller assembly of each of the embodiments of this invention may be provided with a cyclic pitch control mechanism. This mechanism comprises a sleeve 58 rotatably mounted on the shaft 51. This sleeve is attached by conventional linkages to a cyclic pitch control level (not shown) in such a manner that the sleeve 58 can be rotated about the shaft 51 to tilt the swashplate 55. It also is arranged to move axially relative to the shaft 51. These movements of the sleeve 58 are transmitted to the non-rotating portions of the swashplate 55 by means of linkages 59. Such tilting of the swashplate 55 controls the pitch of the blades 19 cyclically through links 56 and the blade horns 57 in the conventional manner.

Aircraft embodiments utilizing the Propeller Assemblies of this Invention

The propeller assemblies may be used on numerous forms of convertiplane.

One convertiplane embodiment has a wing structure that is freely pivoted relative to the fuselage together with twin propeller assemblies carried on separate nacelles mounted on opposite sides of the fuselage.

The use of a pivotable wing structure in a convertiplane has been described in British Patent Specification No. 885,652.

Figure 7 illustrates such a convertiplane, which comprises a conventional fuselage 61 constructed to conform to the requirements of minimum drag in forward flight. The fuselage 61 is equipped with conventional rear elevators and tail 62 and a rudder 63. These conventional components may not be necessary, however.

A wing structure 64 comprising wings 65 extending symmetrically from opposite sides of the fuselage 61 is supported pivotally relative to the fuselage 61 for rotation about a transverse axis X—X. The wings 65 have conventional aerofoil sections for the airplane type of flight and are equipped with conventional ailerons 66 that are adapted to be operated by the pilot from the cockpit by conventional controls (not shown). Nacelles 15 are located at symmetrically spaced-apart points on the wings on opposite sides of the fuselage. In the embodiments shown, the nacelles are at the extremities of the wings 65. Preferably, these nacelles 15 have conventional streamlined external contours. These nacelles contain the aircraft engines, such as the engine 16 shown in Figure 2. Each nacelle

has mounted thereon a variable diameter propeller assembly in accordance with this invention as described above.

The wings 65 are mounted on freely rotatable coaxial shafts 67 (see Figure 8) which extend laterally from opposite sides of the fuselage 61, being supported respectively by bearings carried by the framework (not shown) of the fuselage 61. The wing structure 64 can pivot freely as a unit relative to fuselage 61 about the common axis X—X of the two shafts 67. This pivotal axis X—X is preferably so disposed with respect to the wings 65 as to coincide with the line representing the centre of pressure of the wing structure and associated components (wings, nacelles, rotor assemblies). Moreover, the centre of gravity of the combined wing, nacelles, and rotor assemblies should preferably also be substantially on this pivotal axis. The first condition is required to prevent lift on the wing structure from causing a rotational couple on the wing structure with respect to its free pivotal axis X—X. The second condition minimizes the required control forces for orientation of the wing structure and associated components with respect to the fuselage 61. Further, if both conditions are substantially met there will be no centre of gravity—centre of pressure couple acting on the wing structure tending to turn it about the axis X—X.

No wing position control mechanism other than the cyclic pitch control of the propeller assemblies is provided to pivot the wing structure and associated components with respect to the fuselage 61 about the pivotal axis X—X. The ailerons 66 are provided to enable the centre of pressure to be trimmed to coincide with the pivotal axis. Experiments have shown that propeller blade pitch control through a swashplate, as described above, is quite adequate for pivoting the wing structure and has the added advantage of causing no torque reaction on the fuselage 61 which, being free in space, is incapable of resisting couples without additional provisions.

Other forms of convertiplane equipped with propeller assemblies of this invention can be provided. Thus, referring to Figure 9, a convertiplane has fixed wing structure 65^1 mounted on a fuselage 61^1. Twin nacelles 68 are pivotally secured at symmetrically spaced-apart points on the wing structure 65^1. The nacelles 68 pivot about an axis Z—Z which runs transversely through the wing structure 65^1 and intersects the centre of gravity of the convertiplane 60^1.

The nacelles 68 each carry an engine 69, a drive shaft 70, pitch control means 71, blade retracting means 72 and propeller blades 73, each of the type described above with respect to the first embodiment. This form of convertiplane functions in a fashion similar to that of the first embodiment, with the exception that the nacelles 68 pivot with respect to the wing structure as distinguished from the entire wing structure and nacelles pivoting with respect to the fuselage.

Still another form of convertiplane is shown in Figure 10. In this embodiment, a single nacelle 74, including a propeller assembly 75 is pivotably secured to a stationary member between twin fuselages 76. This embodiment also functions like the first embodiment described above, except that there must be some anti-torque means (not shown) to resist rotation of the fuselage when this embodiment is being operated as a helicopter.

Operation

A convertiplane equipped with at least one variable diameter propeller of this invention is adapted for vertical take-off or landing and for flight as a helicopter and may thereafter be converted into an airplane for high speed forward flight. Considering the aircraft shown in Figures 7 and 8, on the ground the aircraft has the wing disposition shown in Figure 7 in which the wing chords are substantially vertical so that the axes Y_a—Y_a and Y_b—Y_b of the nacelles 15 are substantially vertical with the propellers uppermost, and with all blades substantially horizontal. The engines in the nacelles 15 then rotate the rotors about vertical axes. The engines drive their shafts in opposite directions so that the blades of one nacelle rotate in the opposite direction to the blades of the other nacelle, so that there is no resultant torque reaction on the aircraft as a whole.

In order to take-off, the speed of the engines are increased and the blades 19 are maintained at a low collective pitch of from about 0° to about 4°. Initially, the outboard sections 24 are retracted and as the propellers come up to speed at low pitch the centrifugal force will draw the outboard sections out to their extreme positions. With the engines up to speed and the blades extended, the pilot next increases the collective pitch of the blades to approximately 8° to 10° until he achieves vertical take-off.

After vertical take-off has been effected in this manner, the pilot can, if he desires, continue to manipulate the craft as a helicopter for hovering, forward, backward or lateral flight merely by manipulation of the cyclic and collective pitch mechanisms in a conventional manner with the blades in their fully extended positions.

If he now desires to convert the aircraft into an airplane for high speed forward flight the pilot operates the cyclic pitch mechanism in a direction that causes forward tilt of the plane of both propellers. This simultaneously causes the wing structure 65 to swing forwardly about its pivotal axis X—X from the vertical position into a substantially horizon-

tal position as shown in Figure 8. During this shift of the wing structure 65, and approximately at the time it reaches the horizontal position, the collective pitch control mechanisms are manipulated to increase considerably the pitch of all the blades. The drag of the blades of both propeller assemblies thus increases and their speed decreases. There is a corresponding decrease in centrifugal force on the outboard blade sections and when this force falls below the force exerted through the torque acting at all times on the retracting mechanism, the outboard sections 24 are retracted within the inboard sections 20. With the outboard sections of the blades retracted and maintaining the blades at high pitch settings of about 45° the engines drive the propellers at a high RPM as airplane propellers.

In both the fully retracted and fully extended positions of the outboard sections stop mechanisms (not shown) may be used to arrest longitudinal movement of the outboard sections. These mechanisms may be used at the will of the pilot to maintain full extension or retraction regardless of the rotational speed of the blades, the engine torque or the collective pitch settings of the blades, if so desired.

In order to land the aircraft, the pilot throttles the engines back and reduces the collective pitch of the blades 19. This causes the blades 19 to run faster and increases the centrifugal force acting upon the blades while the engine torque is reduced. The blades are then extended, converting the propellers to the helicopter configuration. Simultaneously, the cyclic pitch mechanisms are actuated to cause pivoting of the wing structure on the X—X axis back to its original position wherein the axes Y_a—Y_a and Y_b—Y_b of the nacelles 15 are substantially vertical as shown in Figure 7. The convertiplane may now be landed like a conventional helicopter.

Although the method by which the invention is to be performed has been particularly described by way of example with reference to a convertiplane having only one pair of variable diameter propeller assemblies, the invention is equally applicable to convertiplanes having more than one pair of variable diameter propeller assemblies.

WHAT I CLAIM IS:—

1. A variable diameter propeller assembly comprising at least one blade having an inboard section and an outboard section retractable with respect to the inboard section, means for retracting the outboard section, and driving means for rotating the blade and for imparting torque to the retracting means, so arranged that when the torque imparted to the retracting means exerts a force on the outboard section that exceeds the centrifugal force thereon the outboard section is retracted.

2. A propeller assembly as claimed in Claim 1 in which the driving means includes power dividing mechanism one branch of which serves to rotate the propeller and the other branch of which serves to retract the outboard section of the blade.

3. A propeller assembly as claimed in Claim 2 in which the power dividing mechanism is so arranged that all the power is transmitted through the branch for rotating the propeller when the outboard section of the blade has been fully retracted.

4. A propeller assembly as claimed in any of the preceding claims in which the retracting means comprises a cable one end of which is secured to the outboard section of the blade within the inboard section while the other end is secured to a winding drum within a hub to which the inboard section is secured, and the driving means serves to transmit torque both to the drum for retracting the outboard section and to the hub for rotating the propeller.

5. A propeller as claimed in any of Claims 1 to 3 in which the means for retracting the outboard section includes a screw mechanism within the blade.

6. A propeller as claimed in Claim 5 in which the screw mechanism comprises a nut fixed to the outboard section of the blade and engaged by a screw rotatably mounted within the inboard section of the blade.

7. A propeller as claimed in any of Claims 1 to 3 in which the blade is mounted on a hub supported by a rotatable hollow mast which transmits to the hub the torque for rotating the propeller, and in which the means for retracting the outboard section of the blades includes a screw within the mast and through which the drive is transmitted, the screw engaging a nut movable longitudinally within the mast but prevented from relative rotation therein, and a cable one end of which is secured to the outboard section of the blade within the inboard section and which passes over a pulley in the hub, the other end being secured to the nut.

8. A variable diameter propeller assembly substantially as described with reference to Figures 2 to 4 or Figure 5 or Figure 6 of the accompanying drawings.

9. A convertiplane equipped with at least one variable diameter propeller assembly as claimed in any of the preceding claims.

10. A convertiplane comprising a fuselage, a wing structure supported for pivoting about an axis transverse to the fuselage and at least one pair of variable diameter propeller assemblies as claimed in any of Claims 1 to 8 carried by the swing structure.

11. A convertiplane as claimed in Claim 10 having cyclic pitch control mechanism for each variable diameter propeller assembly to effect selective pivoting of the wing structure about its axis between a substantially

vertical chord position for helicopter flight and a substantially horizontal chord position for airplane flight.

12. A convertiplane as claimed in Claim 10 or Claim 11 in which the variable diameter propeller assemblies are mounted on nacelles carried by the wing structure.

13. A convertiplane as claimed in any of Claims 10 to 12 in which the pivotal axis of the wing structure substantially coincides with the centre of pressure of the wing structure and its associated components.

14. A convertiplane as claimed in any of Claims 10 to 13 in which the pivotal axis of the wing structure passes through or close to the centre of gravity of the wing structure and its associated components.

15. A convertiplane comprising a fuselage, a wing structure, and at least one pair of nacelles and variable diameter propeller assemblies as claimed in any of Claims 1 to 8 supported on the wing structure for pivoting relative to the wing structure about an axis transverse to the fuselage.

16. A convertiplane as claimed in Claim 15 having cyclic pitch control mechanism for each variable diameter propeller assembly to effect selective pivoting of these assemblies about their pivotal axis between a substantially horizontal rotational plane of the blades for helicopter flight and a substantially vertical rotational plane of the blades for airplane flight.

17. A convertiplane as claimed in Claim 16 in which the pivotal axis substantially coincides with the centre of pressure of the wing structure, nacelles and propeller assemblies.

18. A convertiplane comprising two fuselages, a member extending between the fuselages, and at least one variable diameter propeller assembly as claimed in any of Claims 1 to 8 pivotally mounted on this member.

19. A convertiplane substantially as described with reference to Figures 7 and 8 or Figure 9 or Figure 10 of the accompanying drawings.

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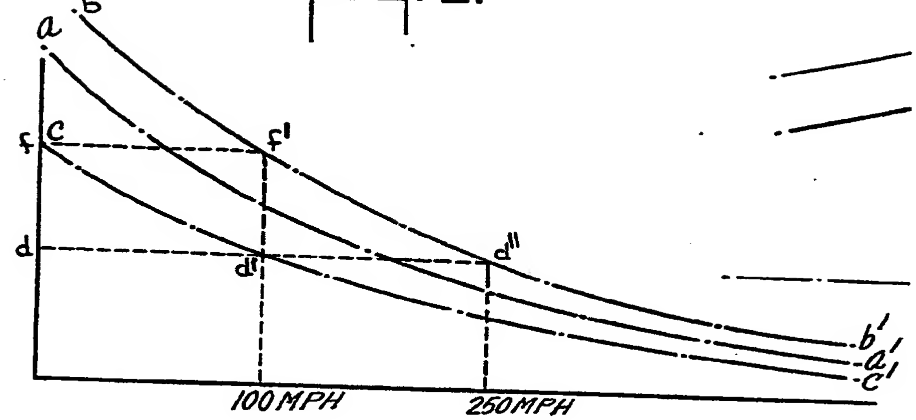
Fig. 1.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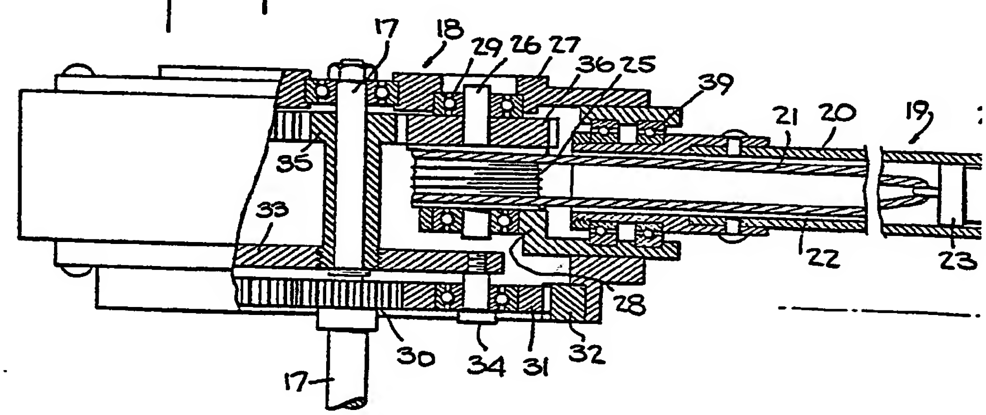
c
f
f'
d
d'
d''
100MPH
250MPH
b'
a'
c'

Fig. 3.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1003940 COMPLETE SPECIFICATION

4 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

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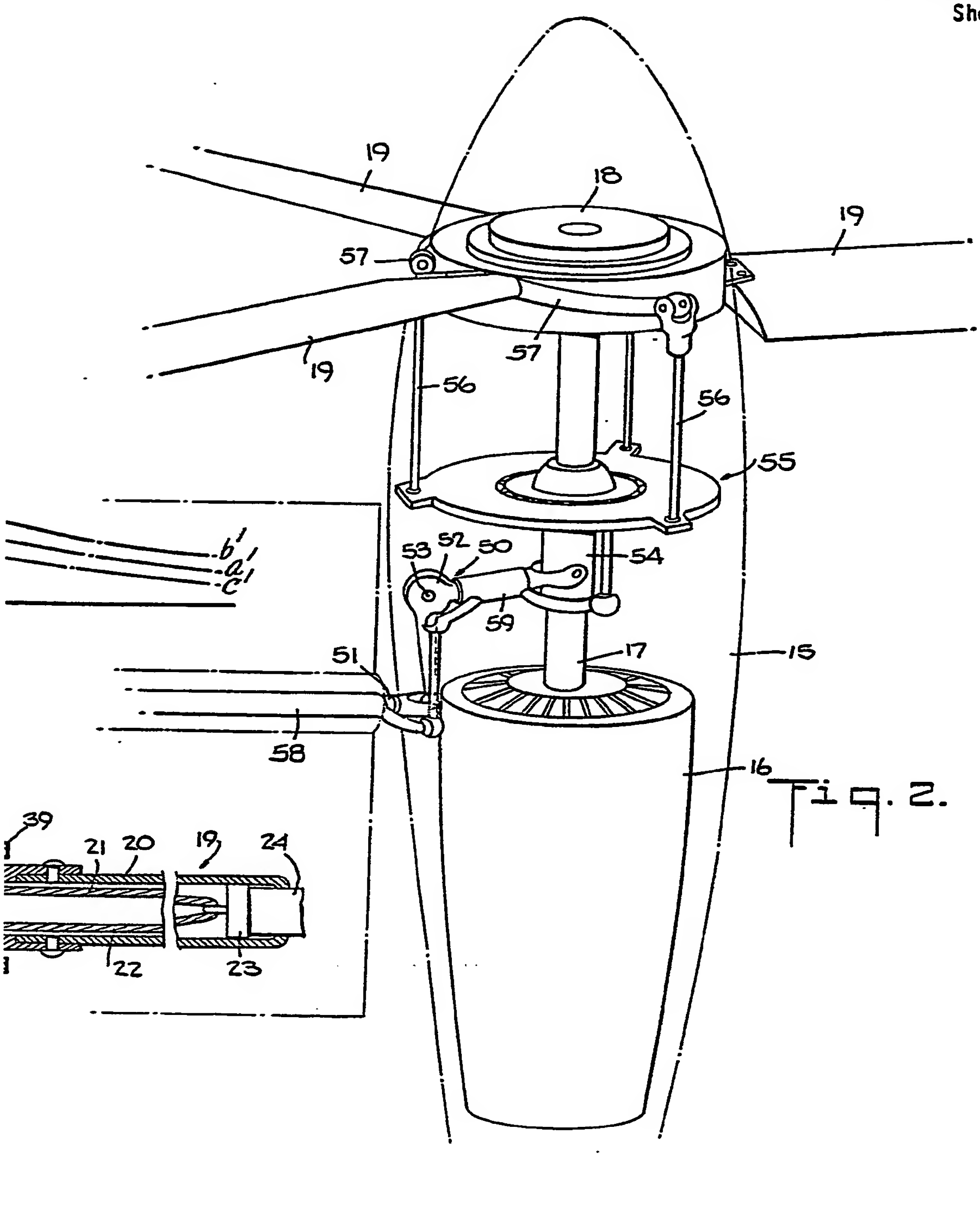
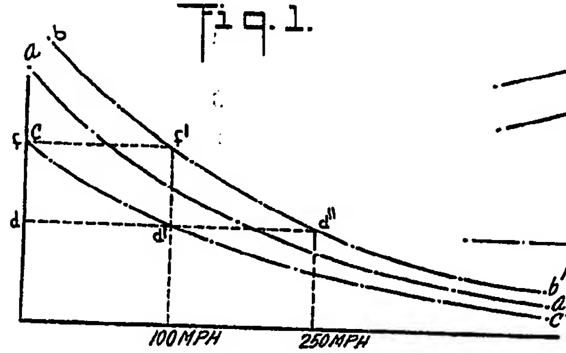


Fig. 2.

Fig. 1.



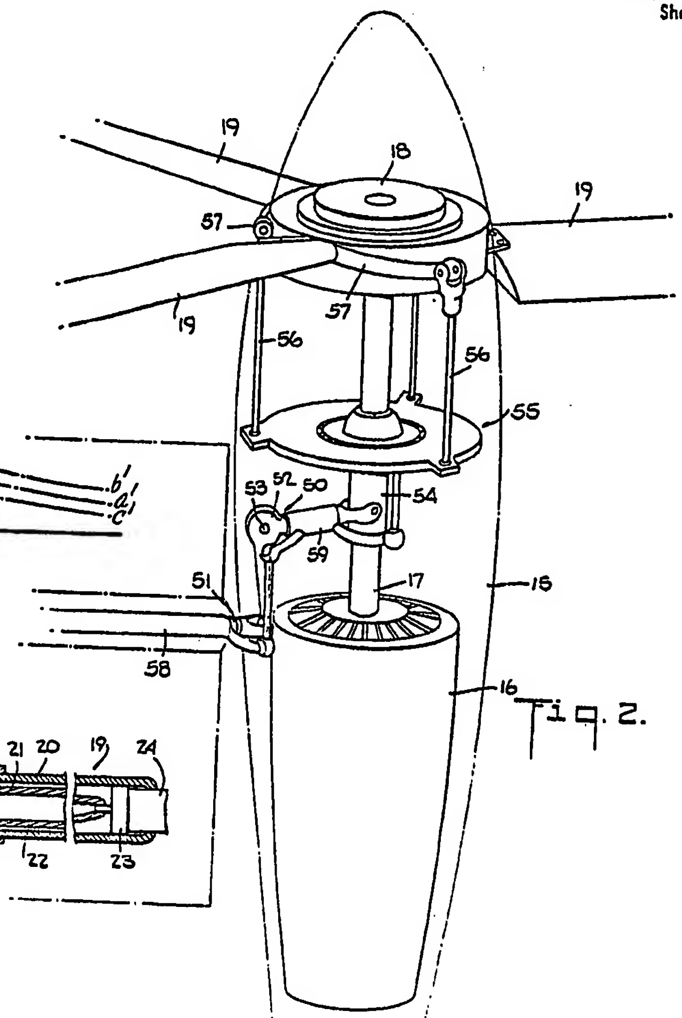
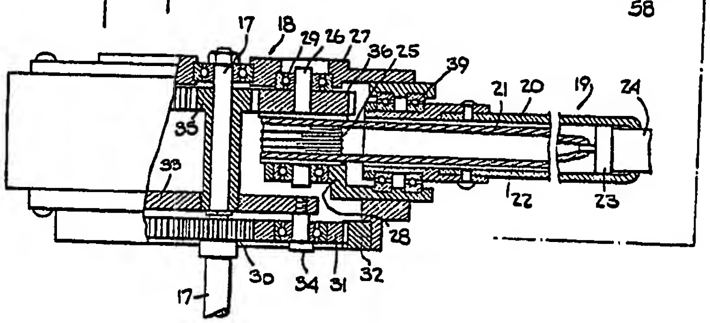


Fig. 2.

Fig. 3.



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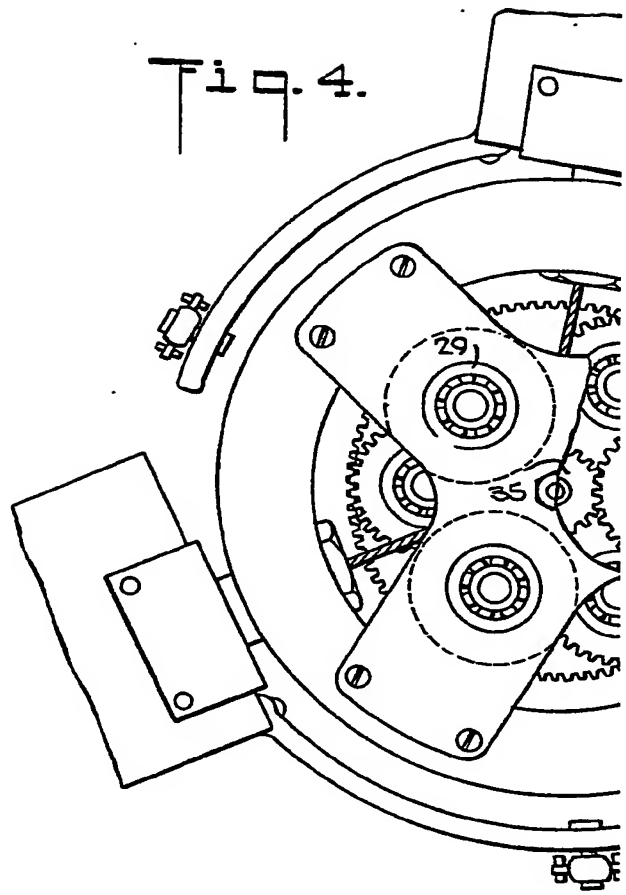

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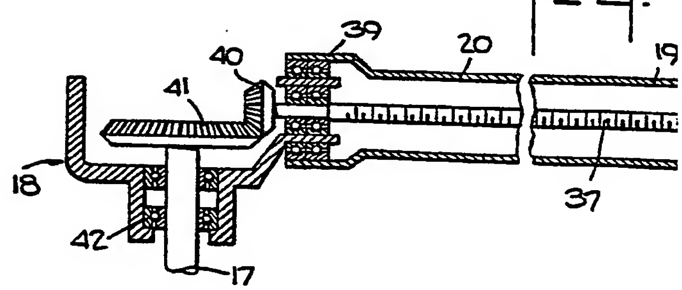

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Sheet 2

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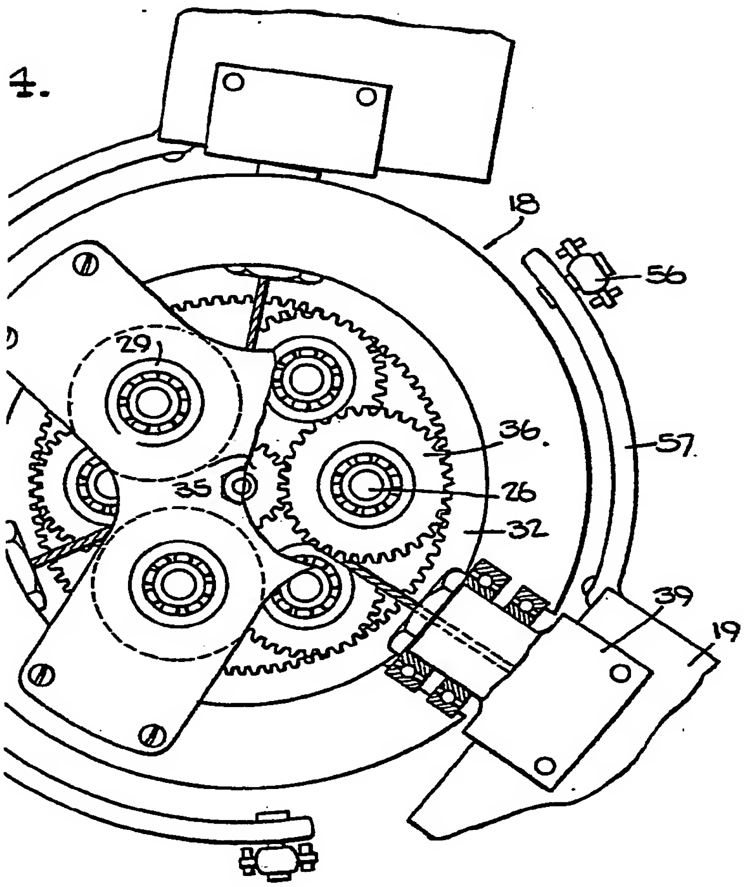

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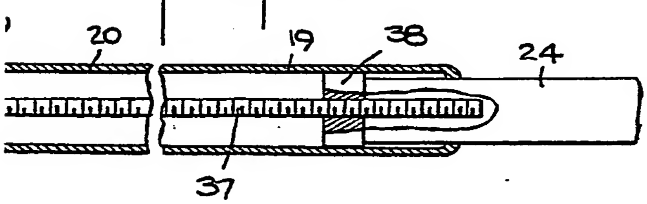

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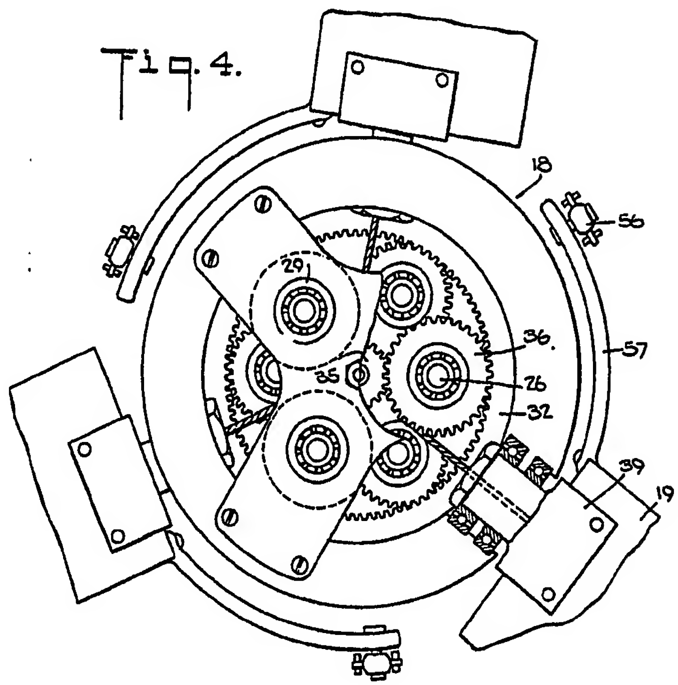

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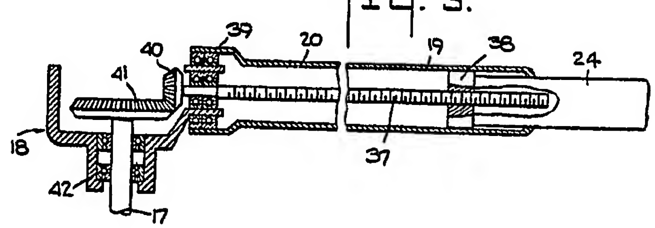

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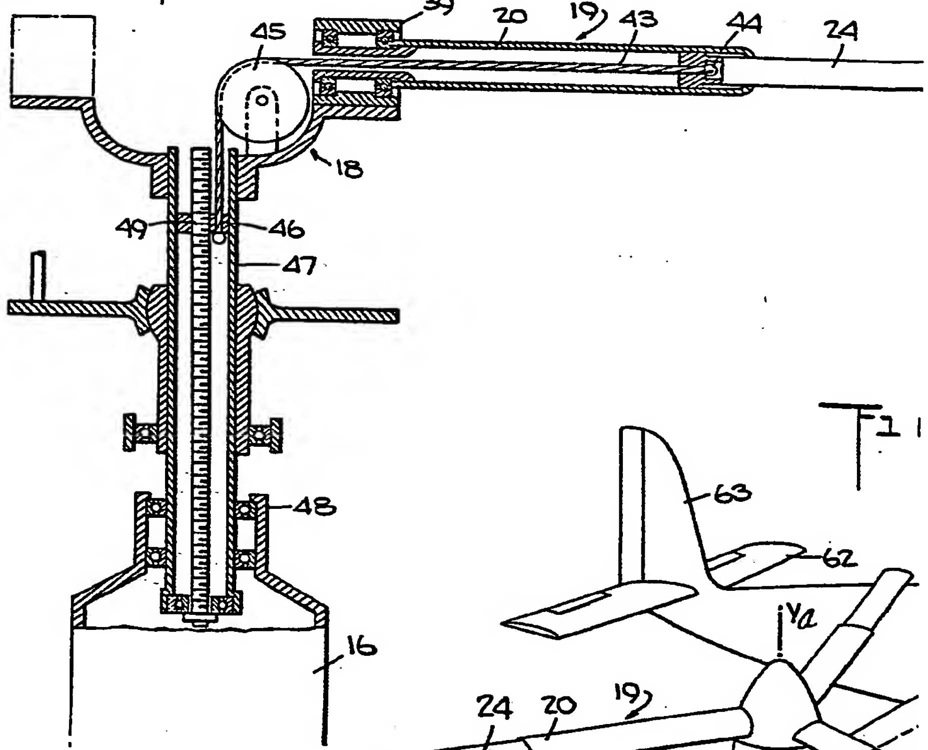

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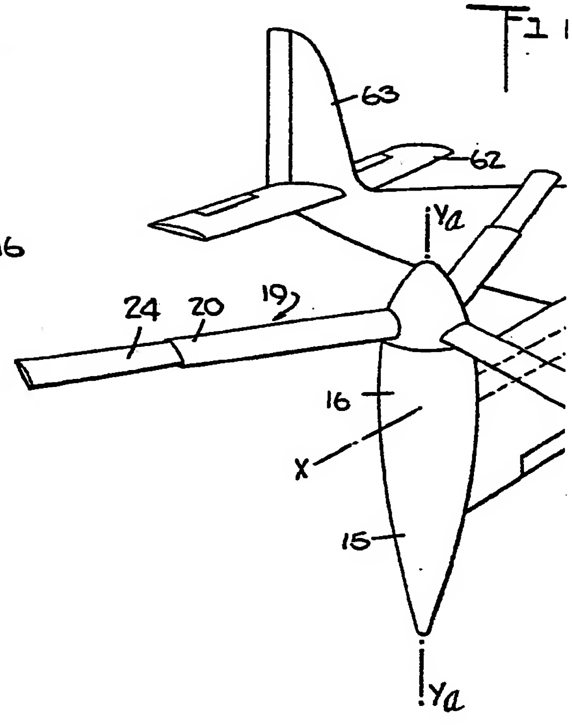

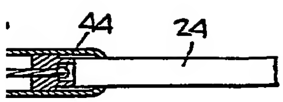

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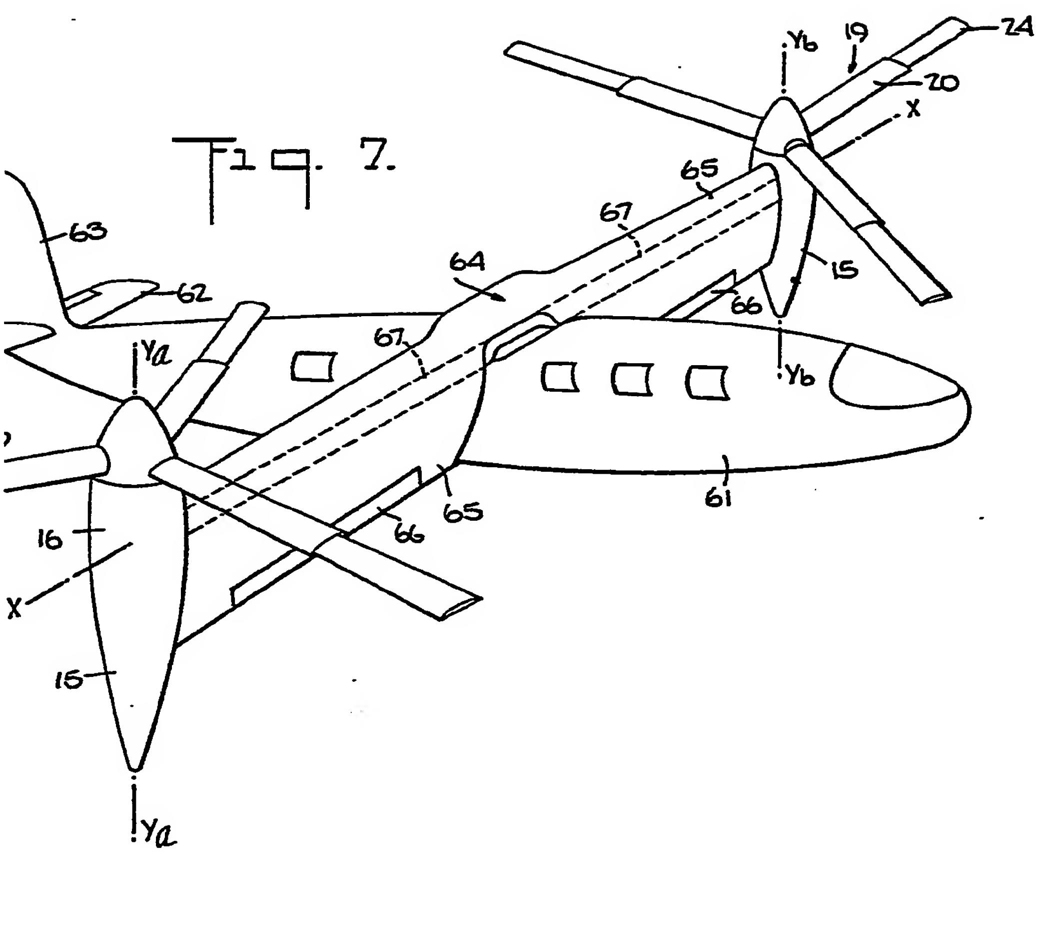

1003940 COMPLETE SPECIFICATION

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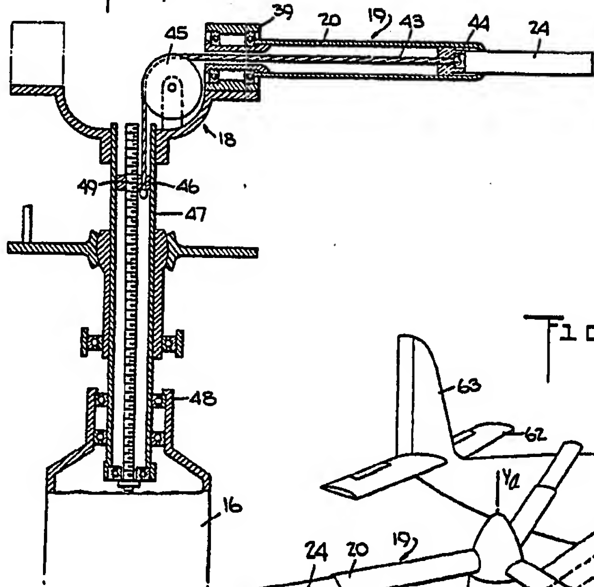
Sheet 3

Fig. 8.



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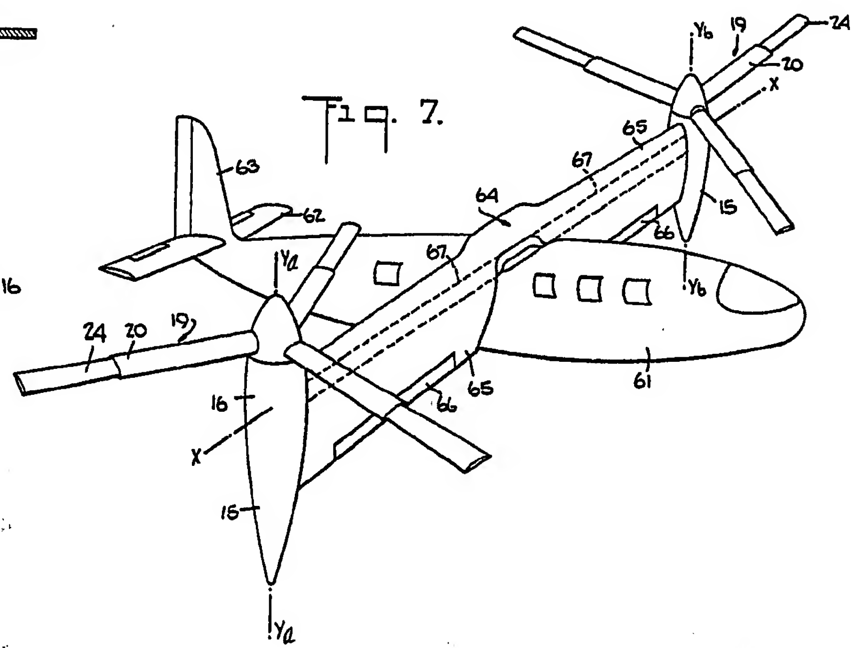


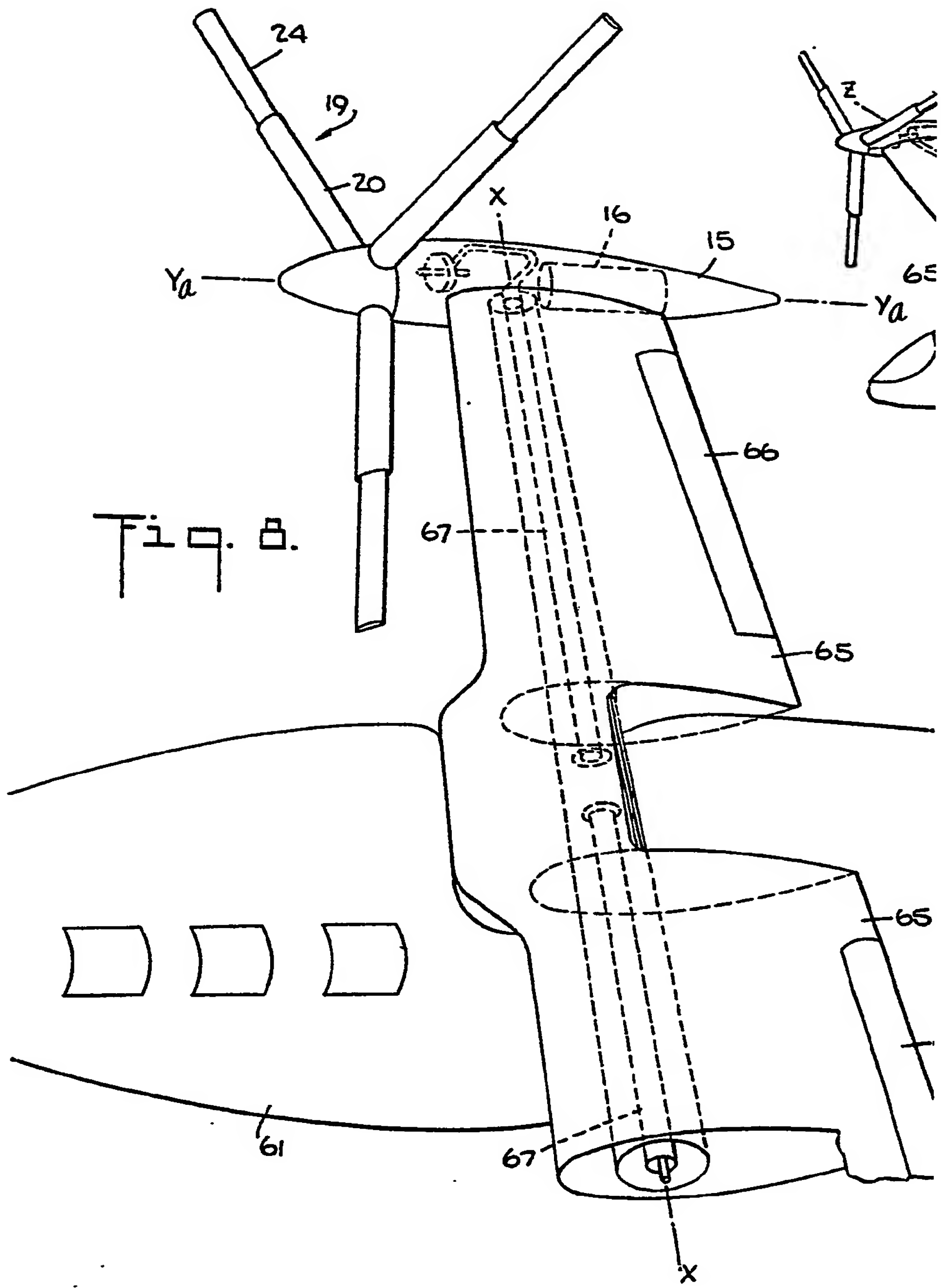
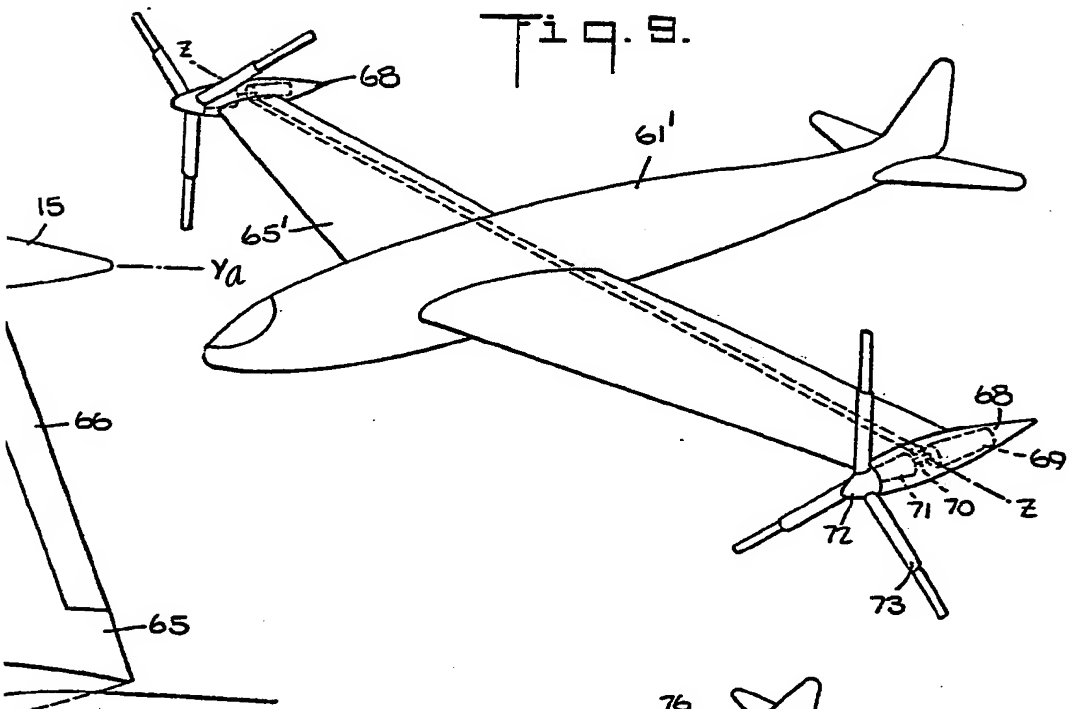
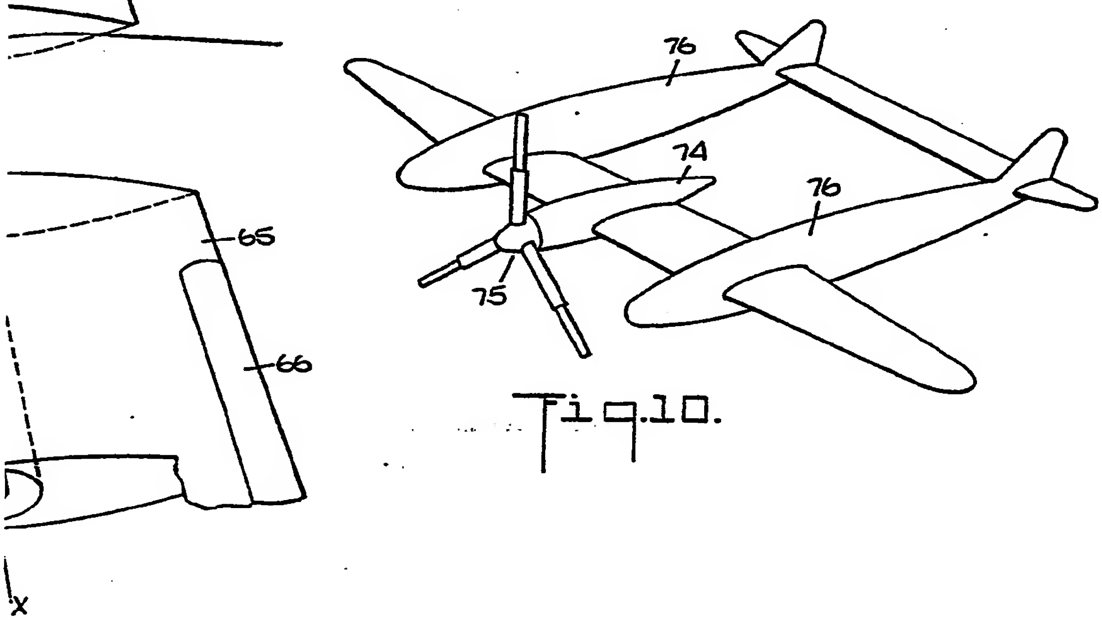


Fig. 8.

1003940 COMPLETE SPECIFICATION
4 SHEETS *This drawing is a reproduction of the Original on a reduced scale*
Sheet 4

Fig. 9.





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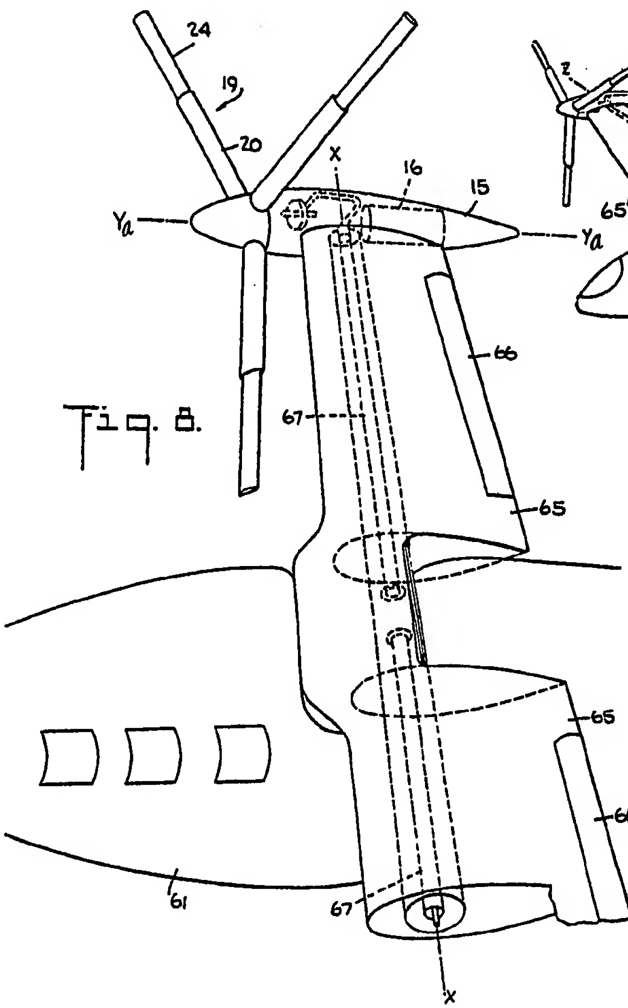

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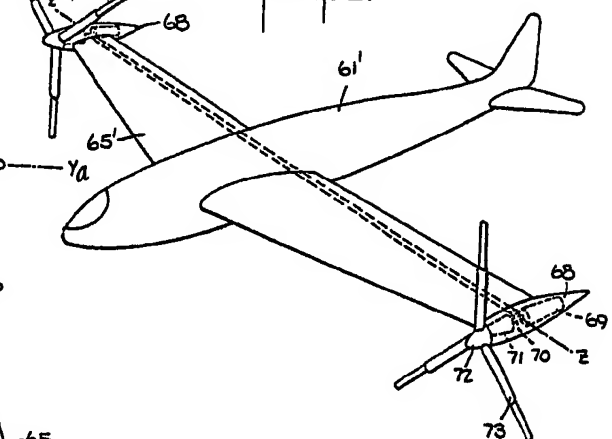

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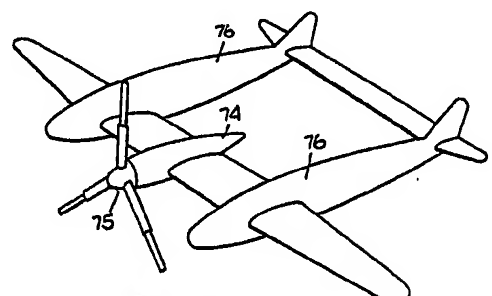

Fig. 10.